1891MNRAS..51..278C

Weiss; J. E. Gore, Catalogue of Binary Stars for which Orbits have been Computed, presented by the Author; Madras Observatory, Meridian Observations made in the years 1868–70, presented by the Observatory; W. T. Lynn, Celestial Motions, 7th edition, presented by the Author; Royal Observatory, Edinburgh, Catalogue of the Crawford Library, presented by the Observatory; L. Becker, The Solar Spectrum at Medium and Low Altitudes, presented by the Author; O. Callandreau, Étude sur la théorie des Comètes périodiques, presented by the Author; R. Wolf, Handbuch der Astronomie, Band I., Theil II., presented by the Author; 17 original negatives of *Jupiter*, made with the 36-inch Equatoreal of the Lick Observatory, presented by Professor Holden; Comparative Photographs of High and Low Sun Spectra, presented by Mr. F. McClean; Stand for Lantern at evening meetings, presented by Mr. W. Schooling; Oxygen bottle, presented by Mr. E. Ristori.

Notes on the Preparations for the Work of the Astrophotographic Chart at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

I. *The Catalogue of Guiding Stars.*

The resolutions of the Permanent Committee relating to guiding stars are as follows:—

11. On prendra comme étoile-guide une belle étoile du champ, dont la position soit connue à 5″ près.

12. Une Commission de cinq membres (MM. Bakhuyzen, Christie, Gill, Kapteyn, Lœwy) est nommée dans le but:

1. De déterminer les positions des centres de toutes les plaques pour l'équinoxe de 1900.
2. De choisir les étoiles-guides et d'assurer leur réduction.

The positions of the centres of the plates decided on by this Commission were published in the fifth number of the *Bulletin* in a paper by W. H. M. Christie. The centres are all at whole minutes of R.A. and whole degrees of declination for the equinox of 1900. The distances in R.A. between centres in the same zone vary from 8 minutes at the Equator to 3 hours at declination +89°; and the centres are so arranged that no star is more than 63′ from the centre of some plate.

As regards the second part of the resolution, the work of selecting guiding stars has been divided amongst the observa-

1891MNRAS..51..278C

tories which expressed their willingness to undertake it as follows:—

Observatory.		Zone in Decl.	Observatory.		Zone in Decl.
Greenwich	...	+90° to +60°	Leiden ...	...	−6° to −9°
Pulkowa ...	...	+59 „ +37	Melbourne	...	−10 „ −14
Leiden ...	...	+36 „ +30	Cape of Good Hope		−15 „ −23
Greenwich	...	+29 „ +25	Groningen	...	−24 „ −40
Paris ...	...	+24 „ + 8	Cape of Good Hope		−41 „ −51
Algiers ...	...	+ 7 „ − 2	Sydney ...	...	−52 „ −64
Greenwich	...	− 3 „ − 5	Melbourne	...	−65 „ −90

Mr. Hollis has been engaged for some time on the zones allotted to Greenwich, and the work is well advanced.

Professor Bakhuyzen proposed the following rules for selecting these stars, suggested by his experience in a preliminary examination of certain portions of the sky:—

1. Generally the brightest star within a circle of 22′ radius from the centre of the plate was to be chosen.

2. If, however, this star was fainter than 9·0 mag., the nearest star to the centre of 9·0 mag. or brighter was to be added as a supplementary guiding star.

Mr. Hollis originally selected stars for the zones +60° to +80° according to these rules, but as he found rather a large proportion of faint stars, the effect of extending the radius of the circle to 30′ was examined. The numbers of stars of different magnitudes found in the two cases are compared in the following table:—

Number of Guiding Stars within limiting circle of

Magnitude.	22′ radius.	30′ radius.
9·5	90	28
9·1−9·4	155	64
8·6−9·0	291	211
8·1−8·5	295	242
7·6−8·0	178	242
7·1−7·5	126	212
6·6−7·0	129	191
6·1−6·5	58	92
5·6−6·0	43	63
5·1−5·5	14	24
Brighter than 5·1	13	23

1891MNRAS..51..278C

The numbers of additional stars required in accordance with the second rule were 277 and 133 in the two cases respectively.

It is to be noted that the co-ordinates of the guiding stars relatively to the centre of the plate are to be measured in the plane of the plate, which is a tangent plane to the sphere, and that corrections will be required to the differences of R.A. and declination between the star and the centre of the plate to convert them into these rectangular co-ordinates in order that the centre of the plate may be set as accurately as practicable to the defined position.

II. *Errors of Réseau.*

The resolutions of the Permanent Committee relative to the réseau are as follows:—

6. Les traits des réseaux auront 130$^{\text{mm}}$ de longueur, leur distance sera de 5$^{\text{mm}}$. Le nom de l'observatoire sera inscrit sur le réseau.

15. Le réseau sera impressionné sur chaque plaque par de la lumière parallèle, dans un châssis placé devant l'objectif photographique lui-même, au foyer duquel on aura placé une source de lumière.

16. On fera usage d'un réseau pour la construction de la Carte.

17. Le réseau, pour la Carte, sera le même que pour le Catalogue.

Two very beautiful silver-on-glass réseaux have been received from Dr. Vogel, the plates being 160$^{\text{mm}}$ square, and lines of 130$^{\text{mm}}$ in length being ruled with a fine point on the silver (so as to leave clear glass) at intervals of 5$^{\text{mm}}$. Arrangements have been made for impressing these on the plate strictly in accordance with resolution 15. A circular metal plate is fitted to the dew-cap of the photographic telescope by four screws. In the centre of the plate is an aperture 140$^{\text{mm}}$ square, opposite which the réseau and plate are to be placed. They are brought into this position in a dark-slide, 8½ inches square, the réseau being held in the dark-slide by four thin plates of silver ($\frac{1}{50}$ inch thick) placed at the corners, which separate the silver film by a very small distance from the sensitive surface of the plate to be impressed.

The corresponding ground edges of the réseau and of the plate bear against three agate planes placed similarly to those determining the position of the plate in the telescope when photographing stars—viz., two agates bearing on the ground edge of the réseau marked A (which is the standard edge for orientation) at 142$^{\text{mm}}$ apart, and one bearing on the middle of the ground edge marked B.

1891MNRAS..51..278C

At the focus of the object-glass is placed a small electric lamp of about $1\frac{1}{3}$ candle-power (6 volts and 0·8 ampère) excited by a secondary battery of four small storage cells, all other light being of course excluded. With this arrangement, which gives a pencil of parallel rays for imprinting the réseau, it is found that an exposure of thirty seconds gives a good image of the réseau on the plate.

With some of the réseaux Dr. Vogel has supplied a table of their errors. This was not done for the Greenwich réseaux, and the errors have been examined at Greenwich. The investigation is not yet complete, but the following results have been obtained:—

(α) The lines are sensibly straight and parallel, or at least are parallel and sensibly similar curves. This seems to have been assumed by Dr. Vogel in the lists of errors he has issued, for he has only given one number applying to the whole line of 130^{mm} in length. At Greenwich the lines parallel to the side B on a photographic copy of one of the réseaux were compared at nearly every 5^{mm} of their length by means of a micrometer (constructed for measuring photographs of the Transit of *Venus*, 1874), with a glass millimetre scale. The distances between them were found to remain constant within the limits of accidental error. The consideration of $16 \times 27 = 432$ residuals shows the limits of possible error. These residuals are grouped as follows:—

	No. of Residuals.
Greater than 0″·50	0
0″·50 to 0·40	2
0·40 to 0·30	9
0·30 to 0·20	40
0·20 to 0·10	140
0·10 to 0·00	241

(β) The errors of the above lines from a uniform scale are very small, and have the following values, if the errors of the millimetre scale, carefully determined at the time the Transit of *Venus* photographs were being measured in 1877, are still valid.

1891MNRAS..51..278C

Réseau line.	Error shown by Comparison with Scale.	Correction to Scale.	Error of Réseau.
	mm.	mm.	mm.
A 1	−0·0222	+0·0120	−0·0102
A 2	−0·0157	0·0121	−0·0036
A 3	−0·0061	0·0073	+0·0012
A 4	−0·0037	0·0096	+0·0059
A 5	−0·0035	0·0116	+0·0081
A 6	+0·0002	0·0105	+0·0107
A 7	+0·0006	0·0106	+0·0112
A 8	+0·0076	0·0047	+0·0123
A 9	+0·0051	0·0066	+0·0117
A 10	+0·0031	0·0082	+0·0113
A 11	−0·0002	0·0095	+0·0093
A 12	−0·0033	0·0146	+0·0113
A 13	+0·0002	0·0137	+0·0139
A 14	−0·0016	0·0114	+0·0098
A 15	+0·0035	0·0108	+0·0143
A 16	+0·0041	0·0108	+0·0149
A 17	+0·0035	0·0079	+0·0114
A 18	+0·0063	0·0101	+0·0164
A 19	+0·0088	0·0052	+0·0140
A 20	+0·0063	0·0093	+0·0156
A 21	−0·0110	0·0234	+0·0124
A 22	−0·0129	0·0268	+0·0139
A 23	−0·0090	0·0254	+0·0164
A 24	+0·0116	0·0031	+0·0147
A 25	+0·0110	0·0036	+0·0146
A 26	+0·0131	0·0041	+0·0172
A 27	+0·0031	0·0129	+0·0160

It is to be remarked that these errors are those of a copy, and the falling off at A 1 − 5 is possibly not the same on the original, but the effect of some photographic accident. The matter is still under investigation.

III. *Course of the Work, Weather, &c.*

It may be interesting to give a few notes of what has been accomplished since regular work was undertaken at the commencement of February. During the thirty-two days from February 9 to March 12, at least two observers have been on the alert from soon after sunset till midnight or later, on all days except three. Fifteen of these nights were completely cloudy; three were partially cloudy, as shown by a small number

1891MNRAS..51..278C

of meridian observations; and eleven were available in some degree for photography, though several were more or less foggy. On these nights twenty-one plates have been exposed either for star-trails (for adjustment, &c.) or for regular photographs, representing a total duration of actual exposure of $12^h\ 49^m$. Better results will, doubtless, be obtained as the work becomes more familiar.

IV. *Star Photographs.*

In respect of the taking of actual photographs, attention must be paid to the following resolutions of the Permanent Committee :—

8. Chacun des directeurs d'observatoires aura la liberté de commander ses plaques à tel fabricant qu'il voudra choisir.

18. On adoptera, pour le temps de pose devant donner les étoiles de grandeur 11·0 le produit par 6·25 du temps de pose nécessaire pour obtenir la grandeur 9·0 de l'échelle d'Argelander.

19. Chaque observateur devra s'attacher à obtenir sur ses clichés destinés au Catalogue la grandeur 11·0, déterminée aussi exactement que possible au moyen de l'échelle d'Argelander que l'on prolongera au-delà de la grandeur 9·0 par l'emploi du coefficient 2·5.

A chacun sera laissé le soin d'apprécier si ses clichés contiennent les étoiles dont la grandeur atteint cette limite.

23. Il sera fait, pour chaque cliché du Catalogue, deux poses successives, la seconde ayant une durée d'un quart de celle de la première et de telle sorte que la distance des deux images soit de 2 à 3 dixièmes de millimètre.

Le Comité recommande aux observateurs de déplacer l'instrument *en déclinaison* pour effectuer la seconde pose, si leur instrument leur permet de la faire, c'est-à-dire s'il est muni d'un micromètre.

With respect to resolution 8 it may be stated that the following plates have been tried: Paget, Cramer, Seed, Star, Mawson and Swan. Our thanks are due to the various makers for the trouble they have taken in cutting plates to the required size and in grinding edges. The selection of the best plate for the work has been a matter of considerable difficulty where the merits are so nearly equal, but after some experience a slight preference is felt for the "Star" plates, if ferrous oxalate development be used.

The most important information with respect to resolution 19 has been derived from two plates taken on 1891 March 4 at $8^h\ 6^m\ +66°$ (one of the adopted centres in the region assigned to Greenwich), the first with an exposure of 30 min., and the second with two exposures of 6 min. and $1\frac{1}{2}$ min. respectively. The northern halves of these two plates were carefully examined, and the diameters of the stars measured. All Argelander's stars in this region were clearly shown with the $1\frac{1}{2}$ min. exposure with the exception of one, D.M. + 67°·519, which is

1891MNRAS..51..278C

shown by the longer exposures to be photographically much fainter than D.M. + 67° ·520 close by. Further, the comparison of the diameters with Argelander's magnitudes gives the following approximate empirical formula connecting diameter in seconds of arc (d), magnitude (m), and time of exposure in minutes (t) :—

$$m = 13{\cdot}80 + 2{\cdot}5 \log t - 8{\cdot}3 \log d.$$

This is not advanced as a final result with full physical significance, but only as a convenient formula, sufficiently true within the limits selected for the work. In deducing it, it was assumed that to produce an image of given diameter, m and t are connected by the relation

$$m = \mathrm{C} + 2{\cdot}5 \log t.$$

It will be seen that this is tacitly assumed in the resolutions of the Permanent Committee, and means that (1) increasing the intensity of the source of light is exactly equivalent to increasing the time of exposure in the same proportion, and (2) the magnitude-ratio is the number whose logarithm is 0·4. The quantity C is a function of the diameter, and it was assumed that the diameter increases as some power of the time of exposure. From a comparison of the 30 min. and 6 min. exposures this power was found to be 1/3·46, and from a comparison of the 30 min. and 1 min. exposures, 1/3·17. The value 1/3·3 was adopted in the formula, which thus becomes—

$$m = \mathrm{C}' + 2{\cdot}5 \log t - 8{\cdot}3 \log d.$$

Finally, the values of C′, as deduced from the stars available, are as follows :—

Star D.M.	Mag. Arg.	C′ 30 min.	C′ 6 min.	C′ 1½ min.
66°·541	6·5	13·51	14·04	14·47
67·538	7·0	13·35	14·51	14·86
66·538	7·8	13·41	13·93	13·93
66·539	8·3	13·59	13·46	13·51
66·548	8·5	14·62	15·12	15·69
66·536	8·8	13·39	13·42	13·53
66·549	8·8	13·99	13·31	12·67
67·520	9·0	14·49	14·85	14·36
66·543	9·1	12·77	12·32	12·49
67·524	9·4	13·91	14·36	14·61
66·546	9·4	14·08	13·91	14·05
66·534	9·5	13·78	14·36	13·67
67·521	9·5	14·23	14·36	13·97
67·523	9·5	13·78	13·88	13·02
67·527	9·5	12·61	13·05	12·22
66·547	9·5	14·16	13·20	13·67
		13·73	13·88	13·80

The value C′ = 13·80 was thus adopted in the general formula.

1891MNRAS..51..278C

From this formula we can deduce the times necessary to obtain stars of a given magnitude on a night actinically similar to 1891 March 4. Mr. Criswick describes this night as "only moderately good, and better at the time of the short exposures than during the long exposure," which accords with the small value of C′ deduced from the long exposure. The night was, however, probably a fair sample of the observing weather which will be available at Greenwich, and the following table will be thus approximately correct:—

Times of Exposure requisite to obtain Discs of given Diameter from Stars of given Magnitude.

Diam. of Disc.	Magnitude.		
	14·0	11·0	9·0
″	min.	min.	sec.
6·0	461	29	277
5·0	252	16	151
4·0	120	7·6	72
3·0	46	2·9	28
2·5	25	1·6	15
2·0	12	0·8	7

It is doubtful whether the formula can be extended much below discs of 3″; the minimum disc visible is something less than 3″ in diameter. A faint photographic disturbance can often be seen with no measurable disc when the place of a star is known from a longer exposure; but for the Chart plates, if the 14th magnitude stars are to be readily discernible, they should probably have a diameter of about 2″·5, and the plates should thus be exposed for about 25^{m} or 30^{m}.

By resolutions 19 and 23 the exposures for the Catalogue plates would thus be 2^{m} and 30^{s}, but in order to facilitate the work of measurement it may be advisable to give rather longer exposures, say 4^{m} and 1^{m}.

The following table shows the diameters of discs of bright stars with exposures of 30^{m}, 2^{m}, and 30^{s} respectively:—

	Magnitude.							
	1	2	3	4	5	6	7	8
min.	″	″	″	″	″	″	″	″
30	97	73	56	42	32	24	18	14
2	43	33	25	19	14	11	8	6
sec.								
30	28	21	16	12	9	7	5	4

These exposures must, of course, be prolonged on bad nights. It is proposed to mount an auxiliary photo-telescope with 4-inch object-glass by Dallmeyer, pointing to *Polaris* or λ *Ursæ Minoris*,

1891MNRAS..51..278C

so that during the long exposure of the plate for the star-chart, a test-plate from the same batch of plates may be taken with a series of short exposures on *Polaris* and rapidly developed (say for 1^m with the standard developer) as an indication of the actinic character of the atmosphere, and as a guide to the exposure necessary to give stars to the 14th magnitude on the Chart plates. From preliminary experiments which have been made, it has been found that a faint image of *Polaris* is obtained with an exposure of 2^s with the Dallmeyer 4-inch telescope.

Variations of Latitude deduced from the Observations of Polaris made at Greenwich, 1851–1889. By Professor H. G. van de Sande Bakhuyzen, Foreign Associate.

The accordance existing between the variations of the latitude deduced from observations made in Berlin, Potsdam, and Prague in the years 1889 and 1890 (*Astron. Nachr.* vol. cxxvi. p. 145) is so evident that it is not possible to explain them by accidental errors. One of the most probable systematic errors which might have caused those variations is an inequality of the refraction at equal distances north and south from the zenith, produced either by an anomalous refraction in the observing-room, or by a configuration of the strata of uniform density in the atmosphere, which is not symmetrical north and south of the zenith.

From an investigation of Professor Albrecht and one of my own, it seems, however, that that error cannot be admitted.

Professor Albrecht has shown that from October 1889 to February 1890 the results of the observations of stars at zenith distances from 2° 38′ to 10° 32′ are the same as those from observations of stars whose zenith distances are comprised between 12° 46′ and 26° 29′ (*Astron. Nachr.* vol. cxxvi. p. 158).

By the courtesy of Professor Helmert, I have received the daily results for the latitude given by each pair of stars observed in Berlin, Potsdam, and Prague from January 1889 to April 1890, so that I could calculate for that whole period the latitudes from observations of stars very near to the zenith. I have employed for that purpose twenty-four stars, whose zenith distances, with the exception of two, are smaller than 5° (the mean zenith distance was 2° 53′). Reducing these observations in the same way as has been followed by Professor Albrecht in the reduction of all the observations, I obtained for the mean monthly results the following values. In the third column I have added the results of the observations of all the stars.